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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

ERT3036 – ADVANCED ROBOTICS

(RE)

(OPEN BOOK EXAMINATION)

14 OCTOBER 2019
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **6 pages** including cover page with **4 Questions** only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please write all your answers clearly in the answer booklet provided.

Question 1

- (a) A mobile robot is represented by point P at the middle of the axis connecting the two motors. The length of the robot is $L = 1$ m and the width is $w = 0.4$ m. Initially, P is located at $(6 \text{ m}, 0 \text{ m})$. It intends to move to a goal position located at point $G (-1 \text{ m}, 0 \text{ m})$. There is a circular obstacle with a radius of $R = 2$ m located with its centre at point $T (3 \text{ m}, -1 \text{ m})$.

Find the following:

- (i) Vector $\overrightarrow{PG}$. [2 marks]
 - (ii) Magnitude $\|\overrightarrow{TP}\|$. [4 marks]
 - (iii) Potential vector due to the obstacle at this point, $\vec{U}$. [9 marks]
- (b) The trajectory for the left wheel of a differentially driven wheeled mobile robot is shown in Figure Q1.

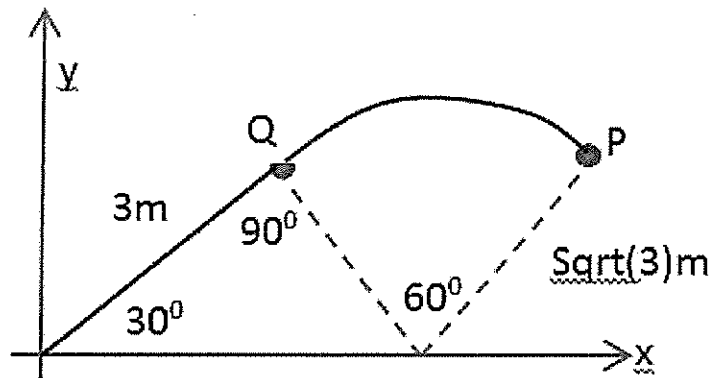


Figure Q1

- (i) Find coordinates for point Q and point P . [5 marks]
- (ii) Find the orientation of point P . [2 marks]
- (iii) If the width of the robot is $w = 0.3\text{m}$, what is the velocity ratio v_2/v_1 for the robot from point Q to point P ? [3 marks]

Continued ...

Question 2

- (a) A 5-link biped robot in frontal plane is shown in **Figure Q2(a)**. Each link is modeled as a point mass at the centre of mass of the link.

(i) When the biped robot is standing using one leg, the zero moment point (ZMP) is located at position y_{ZMP} in the y - z plane. Express y_{ZMP} as a function of point mass (M_1 to M_5) and distance of point mass from the z -axis (y_1 to y_5 and $y_1 = y_2$).

[5 marks]

(ii) Discuss whether y_3 should be at the left of the ZMP or to its right when M_1 and M_2 are vertical along the z -axis.

[4 marks]

(iii) If M_3 also represents total upper body mass, modify the equation found in part (i) to include the acceleration in the y -axis for M_3 , $\ddot{y}$, when the biped robot is walking (ie switching legs). Z_c is the height of M_3 from the ground.

[4 marks]

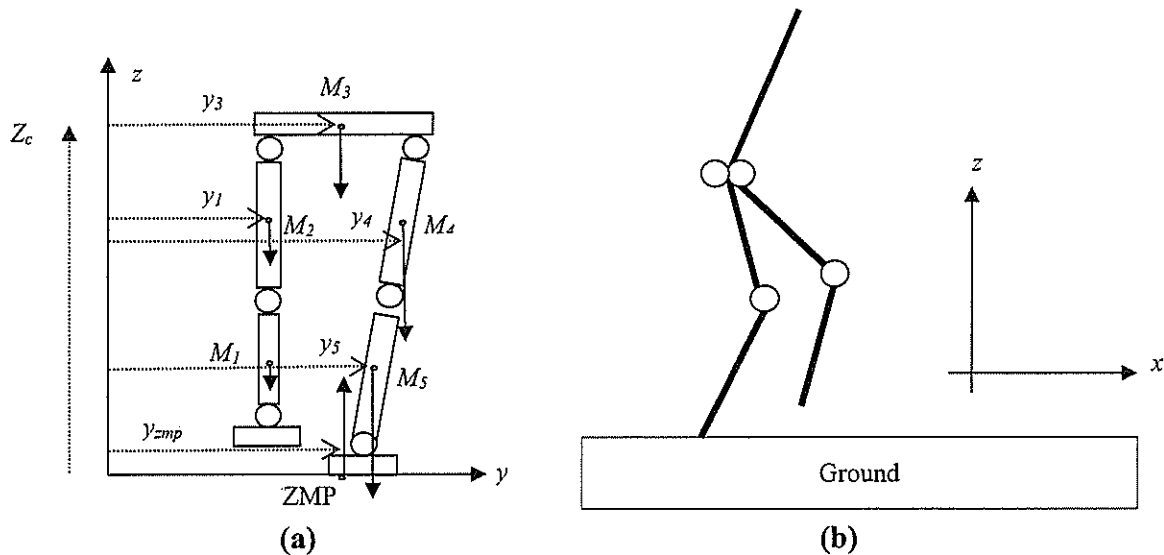


Figure Q2. A model of 5-link robot in (a) frontal plane and (b) sagittal plane

- (b) The five-link biped robot is represented in the sagittal plane as in **Figure Q2(b)**. Describe the mathematical steps to be taken in deriving its dynamic equation.

[12 marks]

Continued ...

Question 3

A quadrotor model with its lifting forces is shown in **Figure 4**. A quadrotor will take off and hovers at a height, z_h and then moves in x direction for a distant x_f , before landing on the ground again.

- (a) Describe a strategy to control the 4 rotors from take-off to hovering. [9 marks]
- (b) Describe how to rotate to a pitch angle of 30° without dropping from its hovering height, z_h . [7 marks]
- (c) For each motor on the quadrotor, the lifting force in is $F_i = 6 \times 10^{-8} \omega_i^2$ N where i is from 1 to 4; and ω_i is the angular rotation of motor- i in rounds per minute (rpm). When the quadrotor is flying in x -direction at a constant height with $M = 0.5$ kg, $\phi = 30^\circ$, $F_1 = 1.1F_3$ and $F_2 = F_3 = F_4$, find ω_3 and $\ddot{x}$. [9 marks]

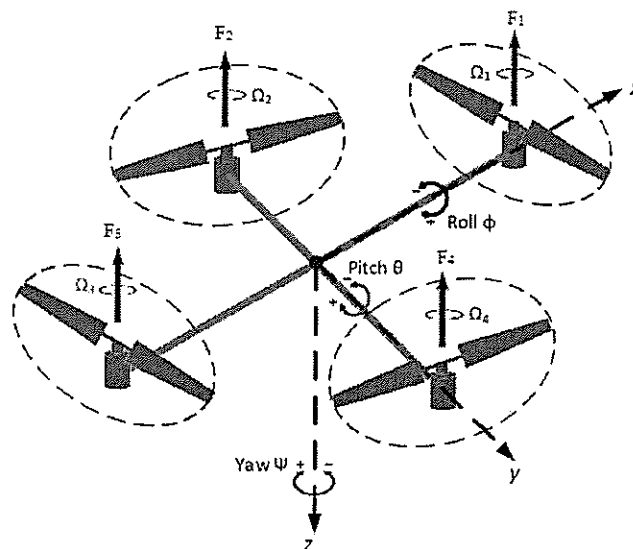


Figure Q4 A quadrotor model with its lifting forces

(source: https://www.researchgate.net/publication/272623829_Fault-tolerant_attitude_tracking_control_for_a_quadrotor_aircraft/figures?lo=1)

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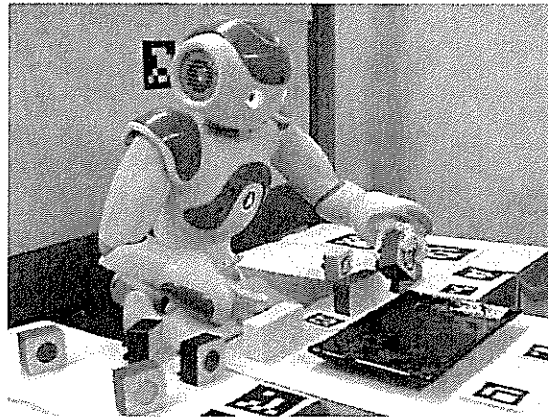
Question 4

- (a) (i) In our community is going to introduce NAO robot, as shown in **Figure Q4.(a)(i)**, as the Social Assistive Robot (SAR) programme in an attempt to reduce human workload. Elaborate on some ethics issues on this initiative before its actual implementation.

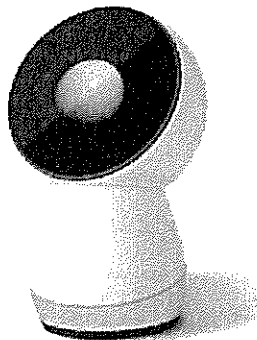
[6 marks]

- (ii) Describe main functionalities for Jibo Social Robot as shown in **Figure Q4.a. (ii)**.

[6 marks]



(i)



(ii)

Figure Q4(a). (i) NAO Robot (ii) Jibo Social Robot

(Source: <https://news.wisc.edu/bridging-the-uncanny-valley-between-humans-robots/>
<https://www.extremetech.com/extreme/186401-meet-jibo-the-worlds-first-family-robot-made-by-mits-social-robotics-master>)

Continued ...

Question 4

(b) A fictitious humanoid robot is playing one-on-one basketball with a human player as shown in **Figure Q4(b)**. The robot is trained in 4 moves: Euro Step, Spin, Jump Shot and Up & Under. For each move, there are 3 attempts for training purpose. The robot is programmed to learn and make decision based on Q-learning algorithm after the 12 training attempts.

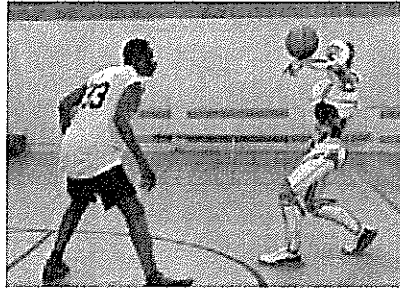


Figure Q4(b). Robot vs Human in Basketball

(i) Complete the Q-learning table, **Table Q4(b)**, by finding the values of the updated Q , when learning rate, $\alpha = 0.5$ and the discount rate, $\gamma = 0.4$. Reward, R , for each made basket is given and there is no reward if the robot did not make the shot.

[10 marks]

(ii) Based on the 12 attempts, which move will the robot make in the 13th attempt? Please justify your answer.

[3 marks]

Table Q4(b). Q-learning Table

				<i>Euro Step</i>	<i>Spin</i>	<i>Jump Shot</i>	<i>Up & Under</i>
			Reward, R	100	50	80	20
Attempt	Move	Made	Q	0	0	0	0
1	<i>Euro Step</i>	1		50			
2	<i>Euro Step</i>	0		35			
3	<i>Euro Step</i>	0		Q_1			
4	<i>Spin</i>	1			25		
5	<i>Spin</i>	1			Q_2		
6	<i>Spin</i>	1			Q_3		
7	<i>Jump Shot</i>	1				40	
8	<i>Jump Shot</i>	0				Q_4	
9	<i>Jump Shot</i>	1				Q_5	
10	<i>Up & Under</i>	0					0
11	<i>Up & Under</i>	0					0
12	<i>Up & Under</i>	1					10

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